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MATG-395US

Appl. No.: 10/813,372  
Amendment Dated November 1, 2006  
Reply to Office Action of August 1, 2006

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**Amendments to the Claims:** This listing of claims will replace all prior versions, and listings, of claims in the application

Listing of Claims:

1. (Currently Amended) A method for manufacturing a microstructure device, which includes at least one fine feature on an existing feature, using a near field scanning optical microscope (NSOM) laser micromachining system including an NSOM and a micro-machining laser, the method comprising the steps of:
  - a) providing a microstructure device preform including the existing feature on a top surface;
  - b) profiling a portion of the top surface of the microstructure device preform with the NSOM to produce a topographical image of the portion of the top surface, the portion of the top surface selected such that the topographical image includes a representation of the existing feature;
  - c) defining an image coordinate system, in terms of settings of the NSOM, for the profiled portion of top surface of the microstructure device preform based on the topographical image;
  - d) determining coordinates of a reference point and an orientation of the existing feature of the top surface of the microstructure device preform in the image coordinate system using the topographical image;
  - e) aligning a probe tip of an NSOM probe of the NSOM over a portion of the existing feature of the microstructure device preform using the coordinates of the reference point and the orientation of the existing feature determined in step (d); and
  - f) machining the top surface of the microstructure device preform with using light from the micro-machining laser coupled through the NSOM probe to form the at least one fine feature on the existing feature, completing the microstructure device.
2. (Original) The method according to claim 1, wherein step (b) includes the steps of:

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b1) selecting the portion of the top surface of the microstructure device preform to be profiled;

b2) aligning the probe tip of the NSOM over a point in the selected portion of the top surface of the microstructure device preform;

b3) determining a distance between the probe tip of the NSOM and the top surface of the microstructure device preform;

b4) controlling the distance between the probe tip and the top surface such that the distance is substantially equal to a profiling distance by moving one of the NSOM probe or the microstructure device preform in a vertical direction;

b5) scanning the probe tip over the selected portion of the top surface while repeating steps (b3) and (b4) to maintain the distance between the probe tip and the top surface substantially equal to the profiling distance;

b6) determining topographical information of the surface based on the vertical movement of the one of the NSOM probe or the microstructure device preform moved in step (b4).

3. (Original) The method according to claim 2, wherein step (b1) includes the steps of:

b1a) optically imaging the top surface of the microstructure device preform to produce an optical image;

b1b) identifying an area of the top surface that includes the existing feature from the optical image;

b1c) selecting the area identified in step (b1b) as the portion of the top surface to be profiled.

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4. (Currently Amended) A method for manufacturing a microstructure device, which includes at least one fine feature on an existing feature, using a near field scanning optical microscope (NSOM) laser micromachining system including an NSOM and a micro-machining laser, the method comprising the steps of:

a) providing a microstructure device preform including the existing feature on a top surface;

b) profiling a portion of the top surface of the microstructure device preform with the NSOM to produce a topographical image of the portion of the top surface, the portion of the top surface selected such that the topographical image includes a representation of the existing feature;

b) selecting a portion of the top surface of the microstructure device preform to be profiled;

c) aligning a probe tip of the NSOM over a point in the selected portion of the top surface of the microstructure device preform;

d) determining a distance between the probe tip of the NSOM and the top surface of the microstructure device preform by~~The method according to claim 2, wherein the step of determining the distance between the probe tip and the top surface of the microstructure device preform includes detecting an atomic force between the probe tip and the top surface;~~

e) controlling the distance between the probe tip and the top surface such that the distance is substantially equal to a profiling distance by moving one of the NSOM probe or the microstructure device preform in a vertical direction;

f) scanning the probe tip over the selected portion of the top surface while repeating steps (d) and (e) to maintain the distance between the probe tip and the top surface substantially equal to the profiling distance;

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g) determining topographical information of the surface based on the vertical movement of the one of the NSOM probe or the microstructure device preform moved in step (e);

h) defining an image coordinate system, in terms of settings of the NSOM, for the profiled portion of top surface of the microstructure device preform based on the topographical image;

i) determining coordinates of a reference point and an orientation of the existing feature of the top surface of the microstructure device preform in the image coordinate system using the topographical image;

j) aligning a probe tip of an NSOM probe of the NSOM over a portion of the existing feature of the microstructure device preform using the coordinates of the reference point and the orientation of the existing feature determined in step (i); and

k) machining the top surface of the microstructure device preform with the micro-machining laser to form the at least one fine feature on the existing feature, completing the microstructure device.

5. (Currently Amended) A method for manufacturing a microstructure device, which includes at least one fine feature on an existing feature, using a near field scanning optical microscope (NSOM) laser micromachining system including an NSOM and a micro-machining laser, the method comprising the steps of:

a) providing a microstructure device preform including the existing feature on a top surface;

b) profiling a portion of the top surface of the microstructure device preform with the NSOM to produce a topographical image of the portion of the top surface, the portion of the top surface selected such that the topographical image includes a representation of the existing feature;

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b) selecting a portion of the top surface of the microstructure device preform to be profiled;

c) aligning a probe tip of the NSOM over a point in the selected portion of the top surface of the microstructure device preform;

d) ~~The method according to claim 2, wherein step (b3) includes the steps of:~~

b3a) generating a periodic oscillation of the NSOM probe of the NSOM in the vertical direction;

b3be) detecting at least one of;

a period of the periodic oscillation of the NSOM probe; or

an amplitude of the periodic oscillation of the NSOM probe; and

b3ef) determining the distance between the probe tip and the top surface based on changes in the at least one of the period or the amplitude of the periodic oscillation detected in step (b3be);

g) controlling the distance between the probe tip and the top surface such that the distance is substantially equal to a profiling distance by moving one of the NSOM probe or the microstructure device preform in a vertical direction;

h) scanning the probe tip over the selected portion of the top surface while repeating steps (d), (e), (f) and (g) to maintain the distance between the probe tip and the top surface substantially equal to the profiling distance;

i) determining topographical information of the surface based on the vertical movement of the one of the NSOM probe or the microstructure device preform moved in step (g);

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j) defining an image coordinate system, in terms of settings of the NSOM, for the profiled portion of top surface of the microstructure device preform based on the topographical image;

k) determining coordinates of a reference point and an orientation of the existing feature of the top surface of the microstructure device preform in the image coordinate system using the topographical image;

l) aligning a probe tip of an NSOM probe of the NSOM over a portion of the existing feature of the microstructure device preform using the coordinates of the reference point and the orientation of the existing feature determined in step (k); and

m) machining the top surface of the microstructure device preform with the micro-machining laser to form the at least one fine feature on the existing feature, completing the microstructure device.

6. (Original) The method according to claim 2, wherein the step of controlling the distance between the probe tip and the top surface of the microstructure device preform includes using a Z motion stage to control a vertical position of one of the NSOM probe or the microstructure device preform based on the distance between the probe tip and the top surface determined in step (b3).

7. (Original) The method according to claim 2, wherein:

the profiling distance is in the range of up to about 50nm; and

the distance between the probe tip of the NSOM and the top surface of the microstructure device preform is controlled in step (b4) with a tolerance of less than 5nm.

8. (Original) The method according to claim 2, wherein step (b5) includes:

b5a) moving the probe tip back and forth across the selected portion in a first horizontal direction to perform a plurality of passes; and

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b5b) moving the probe tip a predetermined distance in a second horizontal direction between each consecutive pair of passes, the second horizontal direction being different from the first horizontal direction, thereby scanning the selected portion of the top surface.

9. (Original) The method according to claim 1, wherein the Image coordinate system Includes X, Y, and Z coordinates for the profiled portion of the top surface of the microstructure device preform, the X, Y, and Z coordinates being respectively scaled to corresponding X, Y, and Z settings of the NSOM determined in step (b).

10. (Currently Amended) A method for manufacturing a microstructure device, which includes at least one fine feature on an existing feature, using a near field scanning optical microscope (NSOM) laser micromachining system including an NSOM and a micro-machining laser, the method comprising the steps of:

a) providing a microstructure device preform including the existing feature on a top surface;

b) profiling a portion of the top surface of the microstructure device preform with the NSOM to produce a topographical image of the portion of the top surface, the portion of the top surface selected such that the topographical image includes a representation of the existing feature;

c) defining an image coordinate system, in terms of settings of the NSOM, for the profiled portion of top surface of the microstructure device preform based on the topographical image;

d) determining coordinates of a reference point and an orientation of the existing feature of the top surface of the microstructure device preform in the image coordinate system using the topographical image; ~~The method according to claim 1, wherein:~~

~~step (d) further includes the steps of;~~

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~~d1e)~~ determining coordinates of two calibration points of the top surface of the microstructure device preform in the image coordinate system using the topographical image, the two calibration points being a predetermined distance apart; ~~and~~

~~d2f)~~ calculating a conversion factor between the image coordinate system and a spatial coordinate system of the microstructure device preform; ~~and~~

g) aligning the a probe tip of an NSOM probe of the NSOM over the portion of the existing feature in step (e) further includes using the coordinates of the reference point and the orientation of the existing feature determined in step (d) and the conversion factor between the image coordinate system and the spatial coordinate system determined in step (d2f); and

h) machining the top surface of the microstructure device preform with the micro-machining laser to form the at least one fine feature on the existing feature, completing the microstructure device.

11. (Original) The method according to claim 1, wherein step (e) includes the steps of:

e1) aligning the probe tip horizontally over a portion of the existing feature of the microstructure device preform; and

e2) controlling the distance between the probe tip and the top surface of the microstructure device preform to be substantially a machining distance based on the topographical image of the portion of the top surface of the microstructure device preform and the image coordinate system.

12. (Original) The method according to claim 11, wherein the step of controlling the distance between the probe tip and the top surface of the microstructure device preform to be substantially the machining distance includes using a Z motion stage to control a vertical position of one of the NSOM probe or the microstructure device preform.

13. (Original) The method according to claim 11, wherein:



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the machining distance is in a range of up to half of a peak wavelength of light generated by the micro-machining laser; and

the distance between the probe tip of the NSOM probe and the top surface of the microstructure device preform is controlled in step (e2) with a tolerance of less than 5nm.

14. (Original) The method according to claim 1, wherein step (f) includes the steps of:

f1) using the micro-machining laser to generate pulses of laser light;

f2) coupling the pulses of laser light into the NSOM probe;

f3) coupling a near-field mode portion of the pulses of laser light through the probe tip of the NSOM probe and onto the portion of the existing feature of the microstructure device preform over which the probe tip is aligned to machine the top surface of the microstructure device preform in the portion of the existing feature over which the probe tip is aligned; and

f4) aligning the probe tip over another portion of the existing feature and repeating steps f1, f2, f3, and f4 until the microstructure device is completed.

15. (Original) The method according to claim 14, wherein:

the micro-machining laser includes a laser oscillator and an attenuator; and

step (f1) includes the steps of:

f1a) using the laser oscillator to generate initial pulses of laser light having an initial fluence; and

f1b) using the attenuator to control the fluence of the initial pulses of laser light, thereby producing the pulses of laser light having a predetermined near-field machining fluence.

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16. (Original) The method according to claim 14, wherein:

the micro-machining laser includes a laser oscillator and a polarization controller; and

step (f1) includes the steps of:

f1a) using the laser oscillator to generate initial pulses of laser light having an initial polarization; and

f1b) using the polarization controller to adjust the initial polarization of the initial pulses of laser light to a substantially circular polarization.

17. (Original) The method according to claim 14, wherein:

the micro-machining laser includes a laser oscillator to generate the pulses of laser light in step (f1) and a shutter to control emission of the pulses; and

step (f4) includes the steps of:

f4a) moving the at least one of the NSOM probe or the microstructure device preform to scan the probe tip over a region of the top surface of the microstructure device preform including portions of the existing feature in which the at least one fine feature is to be machined;

f4b) opening the shutter when the probe tip is scanned over the portions of the existing feature in which the at least one fine feature is to be machined, thereby allowing machining of the at least one fine feature; and

f4c) closing the shutter when the probe tip is scanned over other areas of the scanned region of the top surface of the microstructure device preform, thereby preventing machining of the other areas of the scanned region.

18. (Original) The method according to claim 1, wherein machining the top surface of the microstructure device preform in step (f) includes at least one of:

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ablating device material of the microstructure device preform in the portion of the existing feature over which the probe tip is aligned;

laser-assisted chemical vapor depositing deposition material on the top surface of the microstructure device preform in the portion of the existing feature over which the probe tip is aligned;

exposing photoresist on the top surface of the microstructure device preform in the portion of the existing feature over which the probe tip is aligned;

changing an index of refraction of the device material of the microstructure device preform in the portion of the existing feature over which the probe tip is aligned;

altering a lattice structure of the device material of the microstructure device preform in the portion of the existing feature over which the probe tip is aligned; or

changing a chemical composition of the device material of the microstructure device preform in the portion of the existing feature over which the probe tip is aligned.

19. (Original) The method according to claim 1, wherein the micro-machining laser is one of an ultrafast laser, a pulsed solid state laser, a pulsed dye laser, a microchip laser, a pulsed CO<sub>2</sub> laser, or an excimer laser.

20. (Withdrawn) The method according to claim 1, wherein the microstructure device to be manufactured is at least one of a microstructure mold, a quantum cellular automaton, a coupled quantum dot device, a resonant tunneling device, a multifunction optical array, a diffractive optical element, a beam shaper, a microlens array, an optical diffuser, a beam splitter, a laser diode corrector, a fine pitch grating, a photonic crystal, a micro-electrical-mechanical system, micro-circuitry, a polymerase chain reaction microsystem, a biochip for detection of hazardous chemical and biological agents, a high-throughput drug screening and selection microsystem, a micro-surface-acoustic-wave device, or a micro-mechanical oscillator.

21. (Original) The method according to claim 1, wherein:

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the microstructure device to be manufactured is a micro-mechanical oscillator; and

a resonance spectrum of the micro-mechanical oscillator is tuned by the at least one fine feature machined on the existing feature.

22. (Original) The method according to claim 21, wherein:

step (a) includes the steps of;

- a1) activating the micro-mechanical oscillator;
- a2) determining an initial resonance spectrum of the micro-mechanical oscillator;
- a3) comparing the initial resonance spectrum determined in step (a2) to a predetermined resonance spectrum; and
- a4) determining a desired shape on the existing feature of the at least one fine feature based on the comparison in step (a3); and

step (f) includes machining the at least one fine feature to have the desired shape on the existing feature determined in step (a4) with the micro-machining laser.

23. (Original) The method according to claim 1, wherein:

the microstructure device to be manufactured is a photonic crystal;

the at least one fine feature to be machined is a defect; and

a transmission spectrum of the photonic crystal is tuned by the defect.

24. (Original) The method according to claim 23, wherein:

step (a) includes the steps of;

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a1) determining the transmission spectrum of the photonic crystal;

a2) comparing the transmission spectrum determined in step (a1) to a predetermined transmission spectrum; and

a3) determining a shape of the defect and a defect location based on the comparison in step (a2); and

step (f) includes machining the defect at the defect location and having the shape determined in step (a3).

25-83 (Canceled)

84. (Previously Presented) The method according to claim 1, wherein the microstructure device to be manufactured is a micro-electrical-mechanical system.

85-86 (Canceled)